Atmospheric Profiles, Clouds, and the Evolution of Sea Ice Cover in the Beaufort and Chukchi Seas
Atmospheric Observations and Modeling as Part of the Seasonal Ice Zone Reconnaissance Surveys

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Award Number: N00014-12-1-0232
http://psc.apl.washington.edu

LONG-TERM GOALS

The goal of this project is to examine the role of sea-ice and atmospheric interactions in the retreat of the SIZ. As sea ice retreats further, changes in lower atmospheric temperature, humidity, winds, and clouds are likely to result from changed sea ice concentrations and ocean temperatures. These changes in turn will affect the evolution of the SIZ. An appropriate representation of this feedback loop in models is critical if we want to advance prediction skill in the SIZ. To do so, we will conduct a combination of targeted measurements and modeling experiments as part of the atmospheric component of the Seasonal Ice Zone Reconnaissance Survey project (SIZRS).

OBJECTIVES

- Determine the role of changing atmospheric properties in modifying the evolution of the SIZ in the Beaufort and Chukchi Seas from spring through fall.
- Determine how changes in sea ice and sea surface conditions in the SIZ affect changes in cloud properties and cover.
- Determine the role additional atmospheric profile observations may play in improving the quality of weather forecasts and ice predictions for the SIZ of the Beaufort and Chukchi Seas.
- Adapt a low cost, expendable, air-deployed micro-aircraft to obtain temperature and humidity profiles and cloud top and base heights

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2013**	2. REPORT TYPE	3. DATES COVERED **00-00-2013 to 00-00-2013**

4. TITLE AND SUBTITLE **Atmospheric Profiles, Clouds, and the Evolution of Sea Ice Cover in the Beaufort and Chukchi Seas Atmospheric Observations and Modeling as Part of the Seasonal Ice Zone Reconnaissance Surveys**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Washington,Applied Physics Lab,1013 NE 40th Street,Seattle,WA,98105**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

APPROACH

To achieve these long-term objectives we will conduct observation and model experiments. The SISZR project is an integrated observation and modeling program aimed at understanding the interplay of atmosphere, ice, and ocean in the SIZ of the Beaufort and Chukchi seas (BCSIZ). It will take advantage of routine Coast Guard C-130 domain awareness missions that take place at two-weekly intervals from March through November. As part of the atmospheric observation component of SIZRS, this project will deploy dropsondes during SIZRS flights planned at least monthly from April through October to obtain atmospheric profiles of temperature, humidity, and winds. Cloud top heights will be retrieved using infrared imagers and LIDAR deployed aboard the SIZRS aircraft by other SIZRS projects. Sea surface temperatures, ice concentrations, and floe size distributions will be measured by other components of the SIZRS project as well. Our atmospheric observations will be examined in the context of varying surface conditions (sea ice concentration, ice thickness, and SST) to increase our understanding of atmosphere-ice-ocean interactions and to initialize, validate, and improve our meso-scale atmospheric model. Seasonally changing surface conditions are expected to provide a present day analog for expected future ice retreat. Ultimately we hope to transmit dropsonde observations to forecast centers for potential assimilation into analyses and forecast products. In addition, we will contribute to technology development by adapting and deploying a new generation of truly expendable (<$700) micro-aerial vehicles (Data Hawk and SmartSonde) designed to obtain detailed high-vertical-resolution temperature, humidity and wind profiles and cloud layering information that cannot be obtained with traditional dropsondes. Our vision is that these vehicles will deliver new, inexpensive measurement capabilities for research and operational purposes in the data sparse region of the BCSIZ as well as other regions of the globe. Ron Lindsay (UW) and Zheng Liu, a recenty hired post-doc contributes WRF modeling expertise, Jinlun Zhang (UW) conducts sea ice model experiments. Dale Lawrence and Jim Maslank (CU) contribute to AUV expertise.

WORK COMPLETED

Observations:

- We adapted a commercial GPS-based radiosonde system to operate in a dropsonde mode that can be launched from aircraft.
- We completed the Aircraft Configuration Control Board (ACCB) process including safety of flight test (SOFT) and obtained approval for deploying dropsondes during ADA flights.
- We conducted successful deployments of dropsondes during ADA missions in June, July and August with a total of 26 profiles over the course of 6 days.
- We identified and solve several problems associated with the dropsonde deployment method. We experimented with different devices used to slow the descent of the dropsondes and arrived at a solution that provided desireable descent rates and allowed deployment within the constraints of ADA missions.
- We intercompared satellite retrievals of cloud fraction and cloud top height with observer estimates from C-130 cockpit.
- We assessed the potential of simulatenous CloudSat/Calipso retrievals with dropsondes taking into satellite sampling patterns and spatial and temporal variability. This information will help guide future mission planning.

We worked towards IR-camera based solutions to obtaining cloud top height as an alternate to the CUPLIS-X system (PI, Mark Tchudi, University of Colorado) for which approval is still pending.

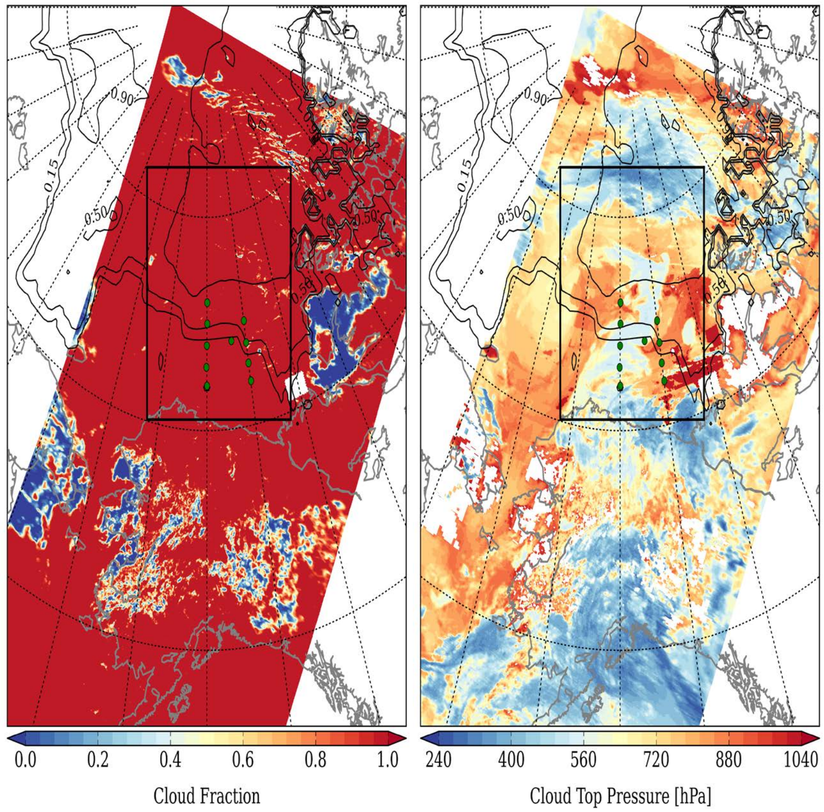

Fig. 1. Terra MODIS satellite-derived cloud fraction and cloud top pressure over the WRF model domain (30 km resolution) around 2200Z during the August 16, 2013 SIZRS mission. The boundaries of the 10 km resolution nest domain is shown in thick black lines. The sea ice concentration contours are shown in thin black lines. The location of dropsondes deployment are shown in green dots.

Modeling:

- A post-doctoral research associate, Zheng Liu, was hired to conduct WRF model experiments
- We conducted Weather Research and Forecast model simulations (WRF) the summer of 2013 and conducted experiments using different resolutions, initalization schemes and parameterizations.
- We intercompared different model runs with SIZRS dropsonde observations and the NCEP Global Forcecast System (GFS) and ERA-Interim reanalysis data. We examined differences in temperature and humidity profiles, horizontal wind speed and the role of clouds in the differences between models runs and observations.

Advanced Observation Playforms (DataHawk, SmartSonde)

- Work on a SmartSonde design to obtain detailed atmospheric parameters and cloud top and base and can be launched from C-130 is progressing. A more detailed report is submitted separately by Co-Investigators Lawrence and Maslanik.

RESULTS

Near surface temperature inversion

The June SIZRS temperature profiles are characterized by a strong near surface temperature inversion as is shown in Fig. 2. The temperature profiles from the WRF simulations and the NCEP Global Forecast System (GFS) and ECMWF ERA Interim (ERA-I) reanalysis reproduced this feature. We followed the Kahl (1990) method to identify the inversion layer and use the temperature change across the inversion (inversion strength) to assess the modeled inversion.

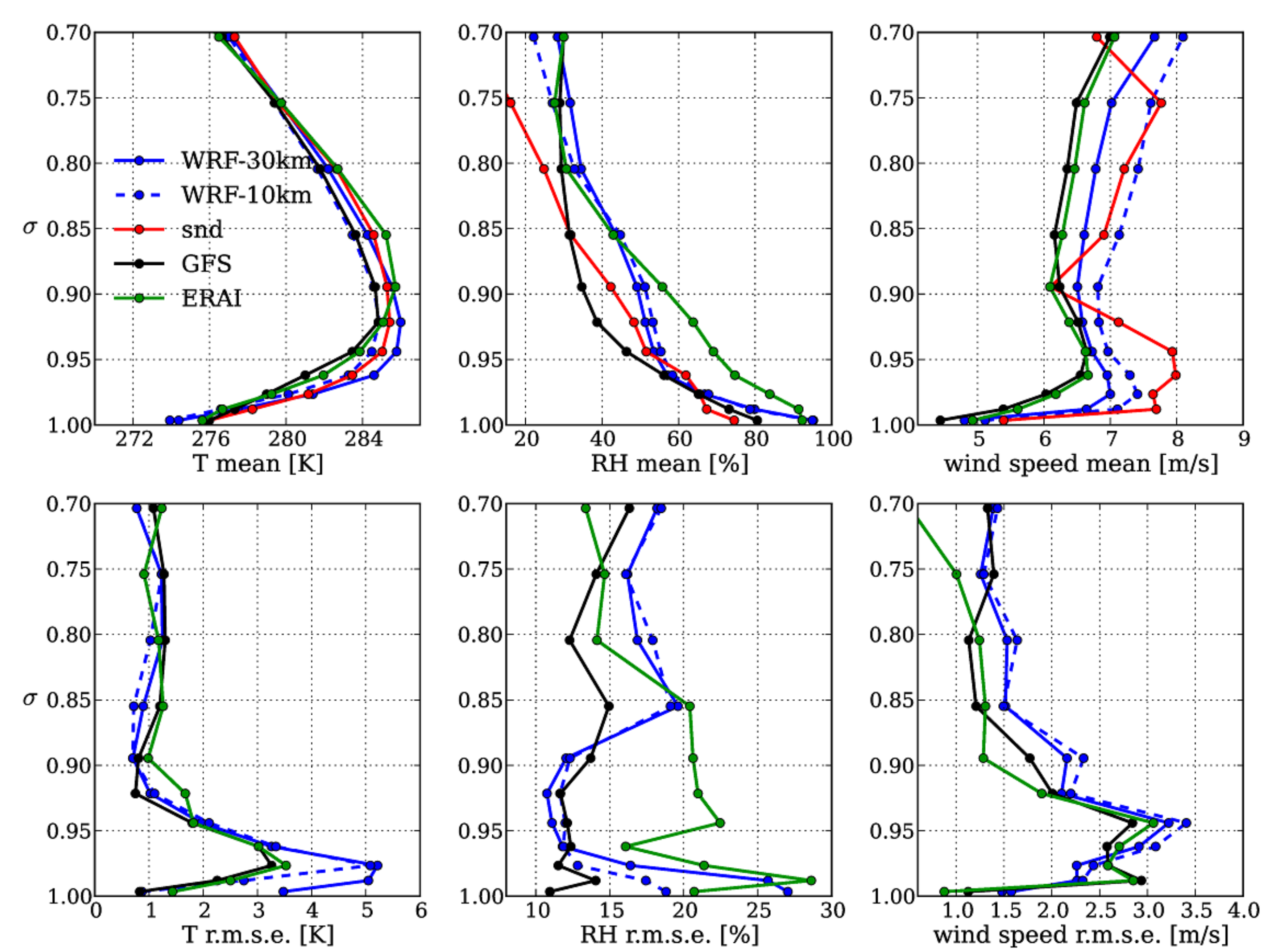

Fig. 2. Comparison of mean and R.M.S.E of temperature, relative humidity and horizontal wind speed for the June 2013 SIZRS campaign. The WRF simulated profiles are shown in blue, with solid lines for the parent domain and dashed lines for the nested high resolution model domain. The dropsonde measurements (snd), the GFS and the ERA-Interim (ERAI) reanalysis data are shown in red, black and green respectively.

The inversion strength, on average, is overestimated in WRF simulations by 1.1 K but underestimated by the GFS and ERA-I reanalysis by 2.1 K and 1.4 K respectively. The root mean square (RMSE) error of WRF simulated inversion strength is 1.7 K, also smaller than the reanalysis (3K), which indicates additional skill by the local WRF implementation. The overestimated inversion strength by WRF is related to a very shallow layer of cloud close to surface, lower than 100 m. It raises the base height of inversion to its cloud top level from the surface and introduces a cold bias to the inversion base temperature by radiative cooling up to 3.5 K.

Bias in reanalysis datasets

The August SIZRS mean temperature and relative humidity profiles suggest a low level cloud layer embedded in a deeper weak inversion layer (Fig. 3). However this feature is not captured by the GFS reanalysis, which has a systematic moist bias over 25% RH above cloud to 780 hPa. Note that WRF simulated RH profiles has a slightly smaller bias and RMSE than the GFS reanalysis, which suggests that although WRF has the potential to improve the forecast, the bias in the forcing dataset is still critical.

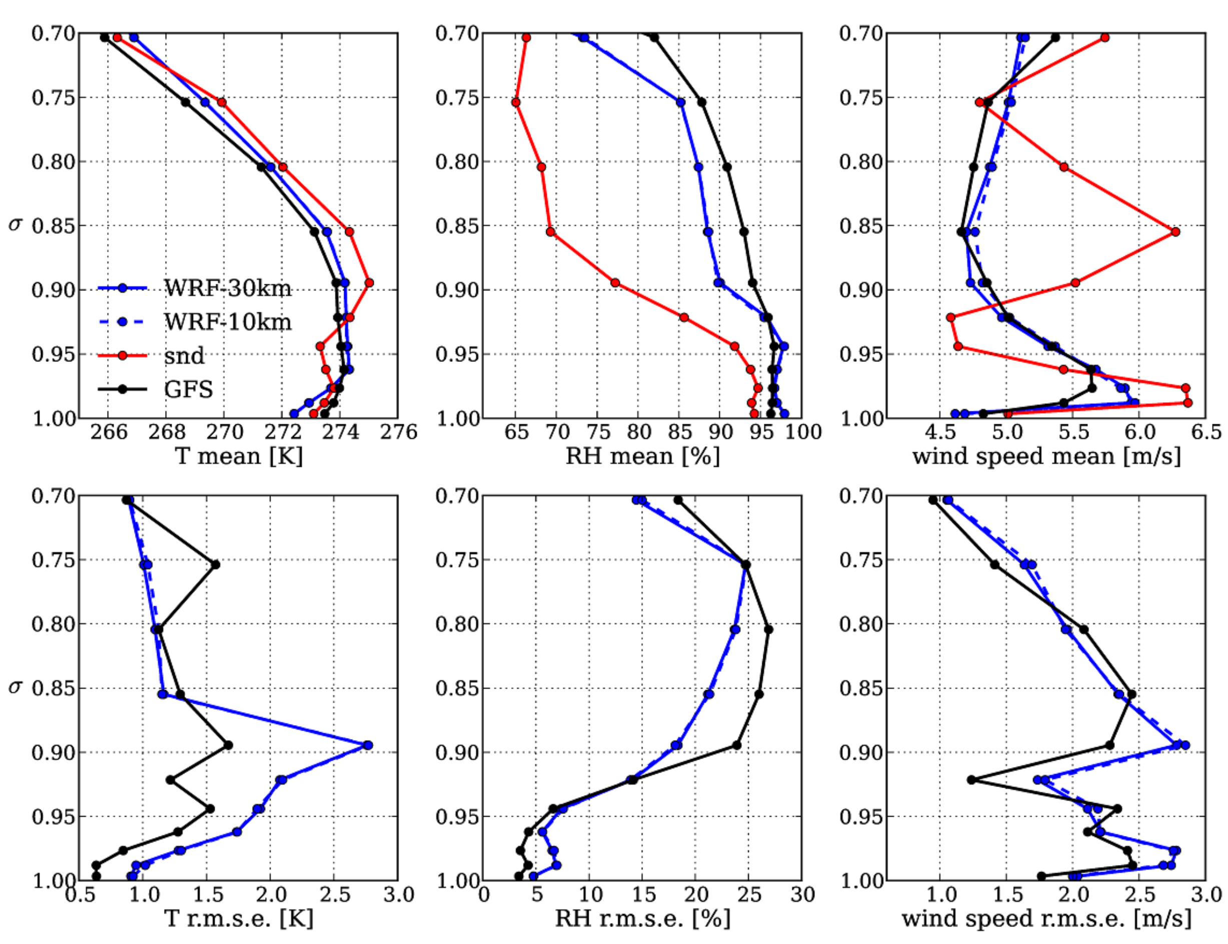

Fig. 3. Comparison of mean and R.M.S.E of temperature, relative humidity and horizontal wind speed for the August 2013 SIZRS campaign. The WRF simulated profiles are shown in blue, with solid lines for the parent domain and dashed lines for the high resolution nest. The dropsonde measurements (snd) and the GFS reanalysis data are shown in red and black respectively.

Another systematic bias in reanalysis is the horizontal winds. The wind speeds are biased low for most levels, especially the low level jet (Fig 2. and Fig. 3). The bias is also evident in the meridional wind speed, which is persistent from surface up to 700 hPa (Fig. 4). Since horizontal winds are nudged at all levels in WRF simulations, it is not likely for WRF to drift far away from the forcing.

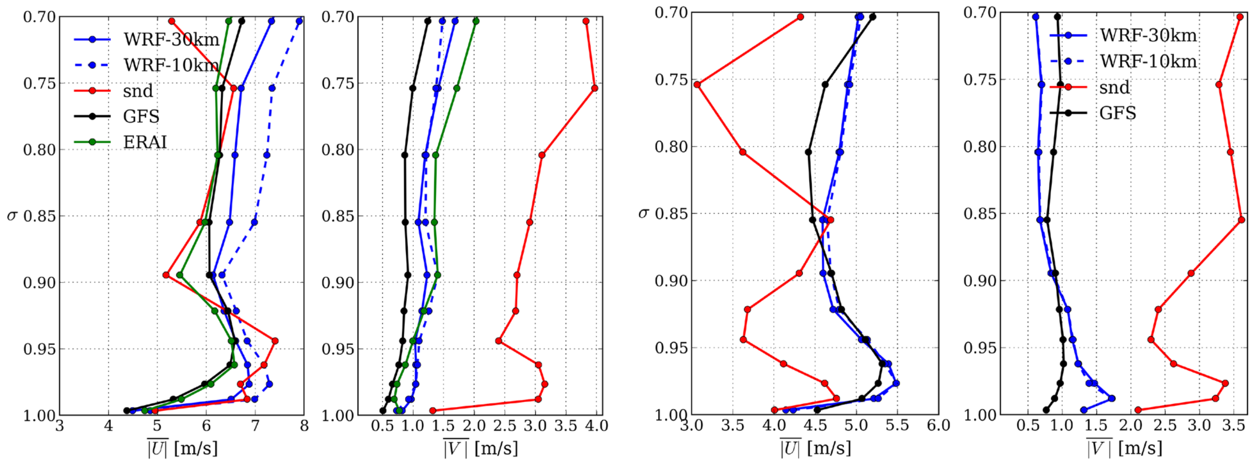

Fig. 4. Comparison of mean |U| and |V| for June (a) and August (b) SIZRS campaign. The WRF simulated profiles are shown in blue, with solid lines for the parent domain and dashed lines for the high resolution nest. The dropsonde measurements (snd), the GFS and the ERA-Interim (ERAI) reanalysis data are shown in red, black and green respectively.

Model resolution and parameterizations

Our WRF simulations have a parent domain with a horizontal resolution of 30 km and a nest domain with a horizontal resolution of 10 km (Fig. 1). The near surface temperature and moisture biases are slightly reduced for the June SIZRS sounding, using the higher horizontal resolution. For the August SIZRS soundings, the higher horizontal resolution shows little advantage. A set of WRF simulations with doubled number of vertical levels are examined. The additional levels have very limited improvements compared to the low resolution runs (not shown).

We experimented with different choices of parameterizations in WRF, e.g., Goddard microphysics vs. Morrison microphysics, MYJ vs. YSU boundary layer schemes and Grell-Devenyi vs. new Simplified-Arakawa-Schubert cumulus parameterization. We found that the inter-model variability is much smaller than the model bias with respect to the dropsonde observations. For example, the June SIZRS temperature profiles, the maximum inter-model standard deviation is 1.2 K, compared to the maximum model bias standard deviation of 5.3 K. Further detailed analysis is required to identify an optimal set of parameters.

IMPACT/APPLICATIONS

The results point the way for future improvement in model simulations. Biases in the inversion strength simulated by models and analysis have potentially important implication for the transfer of energy from the atmosphere to the sea ice during the melt season.

The characterization of biases in model and analysis wind speeds is important for sea ice model development. Sea ice models, driven by winds from atmospheric analysis are senstitive to errors in surface winds.

RELATED PROJECTS

Zhang (PI) MIZMAS: Modeling the Evolution of Ice Thickness and Floe Size Distributions in the Marginal Ice Zone of the Chukchi and Beaufort Sea (ONR, MIZ DRI)

Morison (PI) Ocean Profile Measurements During the SIZRS (ONR Core)

Steele (PI). UptempO buoys for understanding and prediction (ONR-Core)

Lindsay (PI). Visible and Thermal Images of Sea Ice and Open Water from the Coast Guard Arctic Domain Awareness Flights (ONR-Core)

Rigor (PI). International Arctic Buoy Program (ONR-Core)

Morision (PI). SIZRS Coordination (ONR-Core)

PUBLICATIONS

Zhang, J., R. Lindsay, A. Schweiger, and M. Steele (2013), The impact of an intense summer cyclone on 2012 Arctic sea ice retreat, *Geophys. Res. Lett*, n/a-n/a, doi: 10.1002/grl.50190.

Zhang, J. L., R. Lindsay, A. Schweiger, and I. Rigor (2012), Recent changes in the dynamic properties of declining Arctic sea ice: A model study, *Geophys. Res. Lett*, *39*.